Monolithic Polymers Improve Microfluidic Chips

Faster and More Sensitive Detection Achieved

Berkeley Lab scientists Frantisek Svec and Jean Fréchet have developed a new polymer system that dramatically increases the efficiency of microfluidic chips in extracting and concentrating compounds from air, soil, and water samples. The new devices will enable researchers to detect extremely low concentrations of small molecules, proteins, toxins, and microorganisms including those that could be used as chemical or biological weapons.

Microfluidic chips are microscope-slide-sized plates of glass, silica, or plastic that have narrow channels cut into their surfaces. In one application, "sample preconcentration," a liquid sample is injected into one of the channels, the walls of which have been coated with a material that can bind the target agent thought to be in the sample. As the fluid flows through the channel, the target sticks to the channel walls while the remainder of the sample flows through. The absorbed target is later released ("eluted") and concentrated into a very small volume using a solvent that weakens its binding to the walls. Although this method works extremely well, only the channel's walls are coated, thus, only a small portion of the target in a sample is absorbed. The remainder flows through uncollected.

One approach to increasing the extraction efficiency of a microfluidic chip is to increase the effective surface area of the binding material without blocking the channel. The LBNL team worked to accomplish this by filling the entire volume of the channel with a porous "monolithic polymer." The polymer is prepared in the channel by filling it with a liquid mixture of monomers and solvents called "porogens" and exposing it to UV light through a slit in a UV-opaque mask. The resulting polymerization produces a solid material from the monomers but since the porogens remain liquid the contents of the channel appears as a to a sponge-like highly porous material, which completely fills the channel. The porosity and surface activity of the monolithic polymer can be tuned by varying the precursors and reaction conditions. Under optimal conditions the polymer filling is porous enough to allow a sample to flow through the channel with minimal resistance, but not so porous that the surface area for target binding is not significantly increased.

In initial tests, the extraction efficiency of the new polymer was measured using a dilute aqueous solution of an easily observed target: a recombinant green fluorescent protein (GFP). 200 Microliters of the solution were flowed though a channel in which a 7 mm section was filled with the porous methacrylate polymer. The adsorbed protein was later eluted with a water/acetonitrile solution and detected by laser fluorescence. Concentration factors ranging from several hundred to over one thousand were observed, depending on the elution flow conditions.

In ongoing work, Svec and Fréchet are collaborating with colleagues at Sandia National Laboratories, CA. to develop an integrated system using this new material for the detection of biological and chemical warfare agents. This system, called MicroChem Lab, will combine target extraction, separation, and sensitive and definitive detection. In related work, the LBNL team is developing a more sophisticated system for the detection of specific proteins. In this case, the chip will first prepare the sample using enzymes that digest the protein into small defined peptides. The fragment peptides will then be separated, labeled, and finally, detected. Ultimately, such a chip would be useful both for remote sensing and high-throughput laboratory applications.

F. Svec at 510 486-7749 and J. M. J. Fréchet at 510 643-3077, Materials Sciences Division (510 486-4755), Berkeley Lab.

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